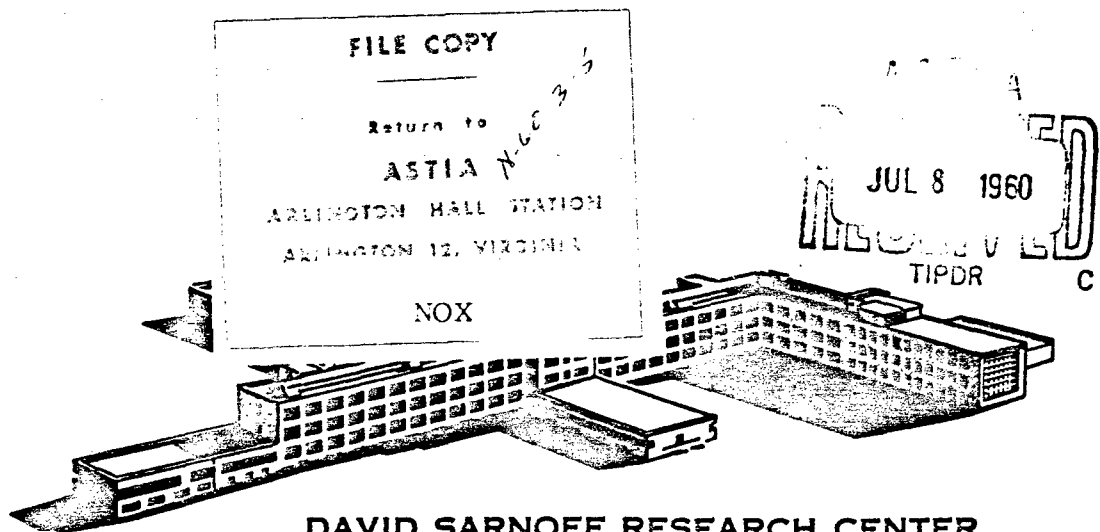


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PRINCETON, NEW JERSEY

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VARIABLE SPEED FACSIMILE

Contract DA36-039-SC-74827

Quarterly Report VIII

May 15, 1960

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Study of Variable Speed Facsimile Scanning Techniques

Quarterly Report VIII

by: Maurice Artzt

This eighth quarterly report contains:

- 1) A description of a new detector system for the FM signal wave that simplifies circuitry and improves the accuracy of synchronism,
- 2) A discussion of further uses of this detector system to obtain effects completely new to the facsimile art, and
- 3) A photo copy of a recording made using the new system which shows greatly improved quality over a recording included in Report VII.

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RCA Order No. 15-14138

May 15, 1959

RCA Laboratories Division  
Radio Corporation of America  
Princeton, N.J.

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## I. Introduction

This is report VIII and will be the last report of this type on this contract. The final report, due in September, will complete the contract. The present report covers work on the project from Jan. 1 to April 29 of 1960.

A sample copy of recording through the entire system was included in the previous report, and showed that the variable velocity scanning system using FM control of both velocity and recording intensity could produce an excellent half tone scale and "almost" acceptable synchronism. Hum was very much in evidence in that recorded copy and accounted for a high percentage of the synchronizing errors. A number of changes in the circuits have been built and tested since that copy was made, all with the object in mind of eliminating the "hum" and improving performance.

These changes have resulted in considerable improvement in the synchronizing, simplification of the recorder adjustments required to align it with the scanner signals, an improvement in recorded detail, and the elimination of about 50% of the hum. The finding of one major source of hum has pointed out two other places where hum could be introduced by a similar use of one type of tube, but time was not available to make these changes before this report was due. It is hoped that completely hum-free recordings can be included in the final report.

A sample copy of a recording made April 25, 1960 is included in this report. All the new circuitry developed in the past four months was used in making this recording. It should be compared to the recording in report VII to show the great gains made in synchronizing and in detection

of fine detail. While hum is still present, it has far less effect on stability of the synchronizing circuits but shows more in the density of the black areas.

Another method of detecting the FM wave has been developed which simplifies the circuitry of both scanner and recorder, and a description of this detector follows. It has been found to be far more stable than the phase-shift detector first used to control both synchronism and the printing density. Independent controls allow the proper synchronism to be established without disturbing the white to black density range or vice versa. With this detector it is also possible to have an infinite density range if desired without disturbing synchronism. Thus high contrast can be obtained for black and white copy or a linear half-tone scale for pictures. Highs can be peaked to bring up the finer detail in small letters. Some of these advantages could be obtained from the phase shift detector but would require elaborate readjustments of the entire system.

## II. Pulse Timer Detector for FM.

A block diagram of the entire scanner-recorder system is shown in figure 2. The detector and sweep circuits are the same for both ends of the system. In addition to these, the scanner has the phototube and FM modulator circuits and the flyback timer for amplitude modulating the FM signal with the phase pulse. The only extra on the recorder is an amplifier for controlling the recording density of black. The grid of the recording CR tube is pulsed "on" for each pulse generated by the Pulse Timer, and is "off" for the in between times.

The heart of the system is the Pulse Timer detector. The FM signal is limited to form a sharp edged square wave. The zero crossings of this square wave are the only information used. With the frequencies used here, 1800 cycles for white and 2400 cycles for black, the zero crossings can be as far apart as 277.78 microseconds, ( $180^\circ$  of 1800 cycles) or as near as 208.33 microseconds ( $180^\circ$  of 2400 cycles). In between values will be a linear function of gray values being scanned.

Two timers of the capacitor discharge type are operated by the limiter output zero crossings. Each timer is adjusted to "count off" 277.78 microseconds and then reset, and as shown in figures 3 and 4, one timer is actuated by each positive going or  $0^\circ$  wavefront from the limiter, and the second timer is actuated by each negative going or  $180^\circ$  wavefront from the limiter. The algebraic addition of the outputs of both timers will give pulses that can be as long as  $277.778 - 208.333 = 69.444$  microseconds for 2400 cycles or black, and the pulses become of zero width at 1800 cycles or white. Both of these conditions are shown in figures 3(D) and figure 4(D).

The sawtooth wave which represents the current in the horizontal coils of the CRT yoke is generated by charging a capacitor to a predetermined upper voltage limit. At this point a discharge circuit is triggered "on" and the capacitor is discharged to a predetermined lower value and held there until released at the end of the time set by the phase pulse timer. The charging of the capacitor is controlled by two circuits, one an accurately regulated constant current that would charge the capacitor to its predetermined limit in 0.222 seconds. This represents

the maximum scanning velocity for solid white subject matter. A second circuit is operated by the pulses obtained from the two timers, (D) in figures 3 and 4. When it is turned on by a pulse it draws discharge current sufficient to overcome the constant charging current and discharges the capacitor at the same rate (-) that the constant current would charge (+) by itself. The spot is thus actually moved backward for the duration of each pulse, and forward for the time between pulses. When scanning black as shown in figure 3, the spot moves forward for 2/3 of each half cycle and backward at the same rate for 1/3 of each half cycle. The net result is the equivalent of a forward motion of 1/4 of a picture element per half cycle of 2400 cycles. Its net forward speed is therefore  $4800/4$  or 1200 picture elements per second. An 800 element line thus requires 0.667 seconds. (Equivalent to 90 rpm for a drum scanner).

On solid white as in figure 4, the pulse width is zero so the scanning is at the constant rate of 1 picture element per half cycle of the 1800 cycle white frequency. The net forward speed is therefore 3600 picture elements per second, and an 800 element line requires 0.222 seconds. This is three times the scanning speed for black.

Values of gray will have pulse widths between the end values of 69.44 and 0 microseconds, and in-between frequencies also, and the net scanning velocity varies linearly with changes in gray. But the exposure of the photo paper per picture element increases as the square between the limits. This is because the time width of the pulses increases linearly with frequency, but the number of cycles per element also increases. This is shown in the following table:



|   | White |      |       | Mid-Gray |       | Black |       |
|---|-------|------|-------|----------|-------|-------|-------|
| FM Freq.  | 1800  | 1900 | 2000  | 2100     | 2200  | 2300  | 2400  |
| Speed Ratio   | 3.00  | 2.67 | 2.33  | 2.00     | 1.67  | 1.33  | 1.00  |
| Elem.per.Sec.                                       | 3600  | 3200 | 2800  | 2400     | 2000  | 1600  | 1200  |
| Exposure time per element in microsecs. and percent | 0     | 17.8 | 40    | 69.44    | 112   | 173   | 277.8 |
|   | 0     | 6.4% | 14.4% | 25%      | 40.2% | 62.2% | 100%  |

Recordings made with this uncorrected exposure showed correct synchronism but poor detail in small letters. This may be partly remedied by adding a high peaking circuit to the exposure timing pulses driving the grid of the CR tube. If carried too far this will increase the density of the light grays too much. However the fine detail can be brought out quite well before the light grays are made too dense.

A better method would be to put a third timer in the amplifier controlling the CR tube grid pulses that limits the grid pulse time width to that obtained at 2100 cycles for mid gray. Pulses from zero width at 1800 cycles up to 39.7 microseconds at 2100 cycles would be used exactly as before. But all pulses which would normally be greater than this value for frequencies higher than 2100 cycles would be limited to the 39.7 microsecond value by the additional timer. In this manner the exposure time per picture element for dark grays and black would be 39.7 microseconds multiplied by the number of pulses per picture element. At black this becomes  $39.7 \times 4 = 158.8$  microseconds instead of the uncorrected 277.8 microseconds. The mid gray exposure has become 44% of black, and

the scale very linear from white to black. This system has not as yet been tested, but will be if there is sufficient time. Its chief advantage over the more obvious method of doctoring the photo tube output to compress black and dark grays is that the linear change in speed with density is retained and synchronism is far easier to establish if this function remains linear.

### III. Additional features of the Pulse Timer Detector.

The charts in figure 5 show in (A), a plot from the table of scanning speed in elements per second vs the FM carrier frequency and in (B), a plot of the exposure time per picture element vs the FM carrier frequency. A dotted curve in (B) shows how the light grays are raised in value by high peaking discussed in section II, and also a third curve showing how the mid-gray to black range is lowered by limiting the pulse width to 39.7 microseconds.

The most interesting features of the detector are shown in figure 5(A). The limiting speed of 3600 elements per second is reached when the pulse width becomes zero at 1800 cycles for white. Lower frequencies than 1800 will not increase the speed beyond this value. The lower speed limit will be reached when the pulses become equal in time width to one half cycle of the carrier frequency for at this point the pulses begin to overlap, and the discharge circuit is "on" 100% of the time. This occurs at a carrier frequency of 3600 cycles, and the speed is then -3600 elements per second. At the frequency of 2700 cycles the pulse width is one half the time duration of one half cycle of carrier

so the (+) and (-) motions of the spot are equal and the net spot velocity is zero. This ability to change scanning speed from a (+) maximum through zero to a (-) maximum merely by changing frequency allows many combinations of speed vs density to be used, some rather extraordinary in the facsimile art.

For example "Ox plow" scanning (linear back and forth) becomes possible by shifting the frequency spectrum for the return scan. If the forward scan uses 1800 cycles for white and 2400 cycles for black, a 3 to 1 speed range is obtained for white speed vs black speed, and by then moving the spectrum up to 3000 cycles for black and 3600 for white, a -3 to -1 speed range is obtained for the return scan. In this manner correct synchronism would be maintained for a true variable speed back and forth scanning system.

There is another method of using Pulse Timing for scanning and in this second method, the two timers are set for 208.33 microseconds (one half cycle of 2400 cycles). Pulses will be of zero width at 2400 cycles for black and increase in time width until at 1800 cycles for white the time width per pulse is 69.44 microseconds. For scanning with these pulses, a constant current is used to charge the scanning capacitor at a rate that will scan a full 800 element line in  $2/3$  seconds, so the constant charge is at the black rate. For the duration of each pulse a second current is added that is eight times the value of the fixed current. Each half cycle of the carrier thus has 208.33 microseconds charging at unit current, and the time length of the pulse charging at 9 times unit current. For white at 1800 cycles the charging time total is 277.8

microseconds of which 208.33 is at unit rate and 69.44 is at 9 times this rate. This adds to the equivalent of 833.33 microseconds at unit rate, which is four times the black value of 208.33 at unit rate. If the charge of 833.33 microseconds represents 1 picture element per 1/2 cycle of 1800 cycles, the 208.33 microseconds will be 1/4 element per half cycle of 2400 cycles for black. This is the same relationship established for the first method and gives the same results in speed variation with frequency.

However this second method would require detection in the first manner to actuate the CR tube beam brilliance, otherwise it would print a negative. In addition the synchronism would be more difficult. In the first method the higher speed for white is fixed, and as this speed is used for the greater part of the average scanning line, some irregularities in the pulse controlled black speed will have a minimum effect on the overall accuracy. In the second method the accurately fixed speed is the slower black rate, and the same irregularities mentioned above would be changes in the white speed and therefore have 3 times the effect on accuracy. It was for this reason that the first method was chosen rather than the more complicated detection system required to isolate speed control and recording density.

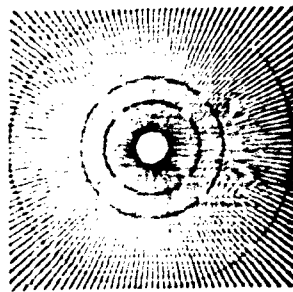
In the second method, pulses disappear for all frequencies greater than 2400, so the lower speed limit is the black rate. At lower frequencies the pulses become a progressively larger percentage of each half cycle, and the speed increases up to a maximum of 9 to 1 at zero frequency.

Of course the order of white and black frequencies may be reversed, making white the higher frequency, and either of the two detection timer systems reversed to give the same 3 to 1 speed range as now used.

#### IV. The Sample Recording, Figure 1.

Figure 1 is a photographic reproduction of a copy made with all improvements up to the starting of this report. The speed ratio was 3 to 1 of white to black, and the black speed set at 800 elements (one scanning line) in  $2/3$  of a second. The white speed is therefore 0.222 seconds per scanning line. A phase pulse of 5 milliseconds duration was used, so the net use factor at the highest speed is 97.7%. High peaking was used to bring out the lighter grays and increase the intensity of small type where the actual detail required is about 7 mils for readability.

If hum was not present, the copy would be near perfect. Synchronism is better than previous copy using the phase shift detector, and it should be pointed out that another copy was run through several hours later and showed no observable changes. The equipment was left on all of this time, but no readjustments were made. This could not be done on the phase shift detector without readjustment, for drifts were too high. The present equipment becomes stable after about 20 minutes warm up time, and most of this is required for the FM oscillator system to stabilize.



Resolution Medium (Unreduced)  
 100% 100% 100% 100% 100%  
 100% 100% 100% 100% 100%  
 100% 100% 100% 100% 100%

Resolution Medium (Unreduced)  
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# IRE FACSIMILE TEST CHART

Fig. 1 Print using smooth forward scanning on white and variable pulse width reverse scanning for gray and black.

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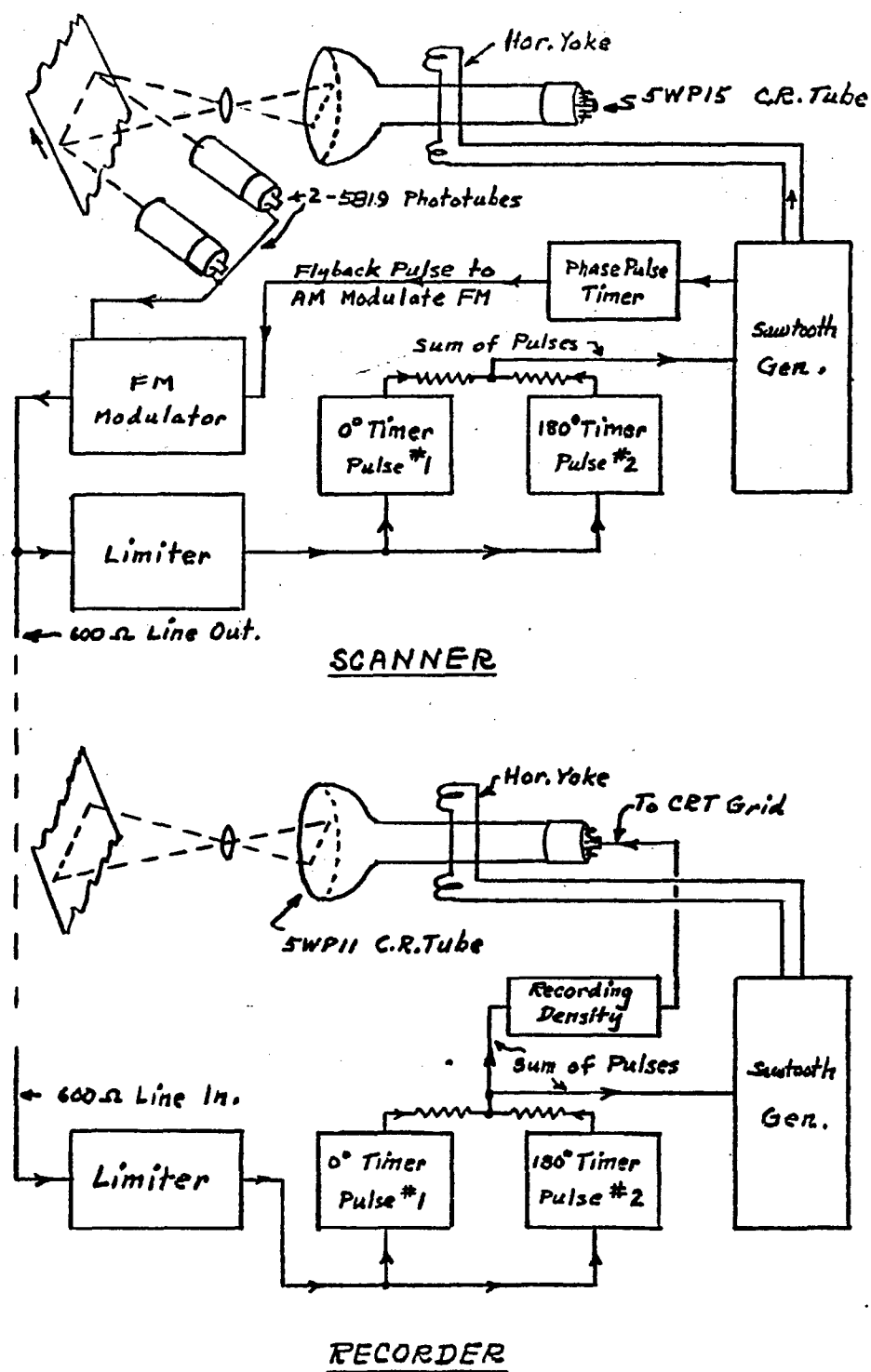
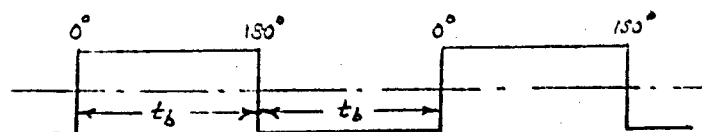


Fig.2. Block diagram of pulse timer detector system.

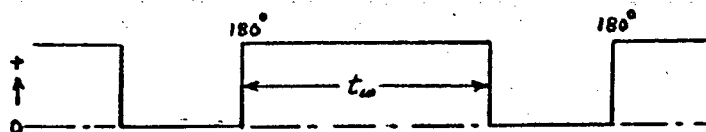
M. ARTZT  
May 2, 1960



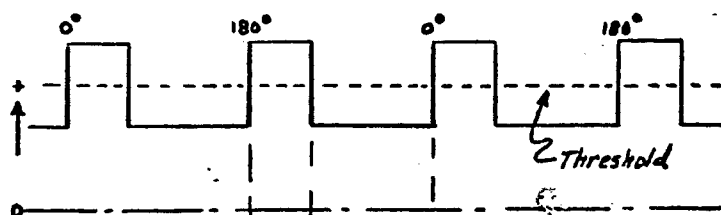
(A.)  
Black Freq. 2400N  
Square Wave



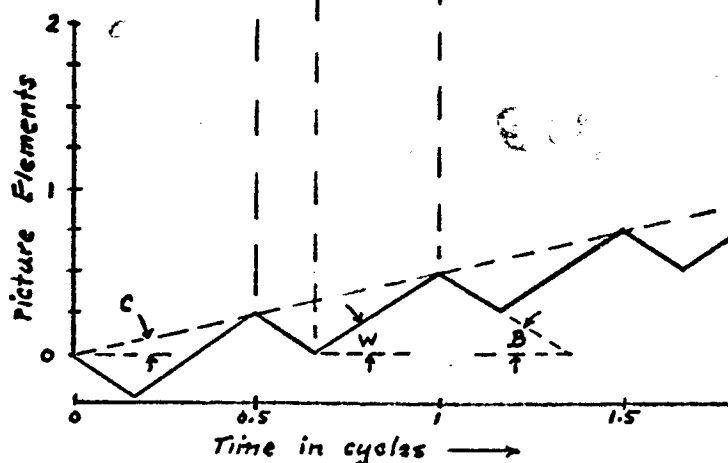
(B.)  
Pulse #1. Timer set  
at 0° crossings.



(C.)  
Pulse #2. Timer set  
at 180° crossings.



(D.)  
Sum of Pulses #1 & #2.  
Pulses above threshold  
used to reverse scan  
direction.

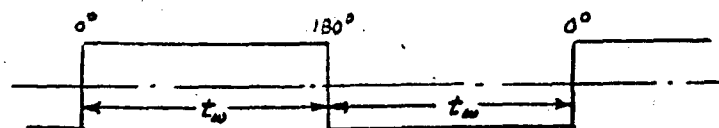


(E.)  
current to yoke.  
Angle W is linear  
rise for white.  
Angle B is reverse  
for pulse duration.  
Angle C is average  
Black scan rate.

Fig. 3 Scanning black copy with pulse time control.

M. ARTZT  
May 2, 1960

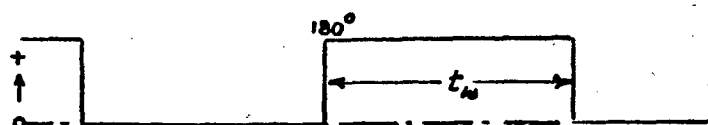




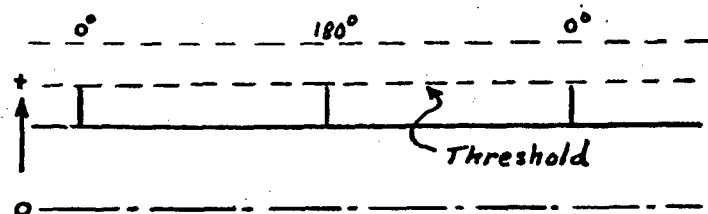
(A.)  
White Frog. 1800 W  
Square Wave



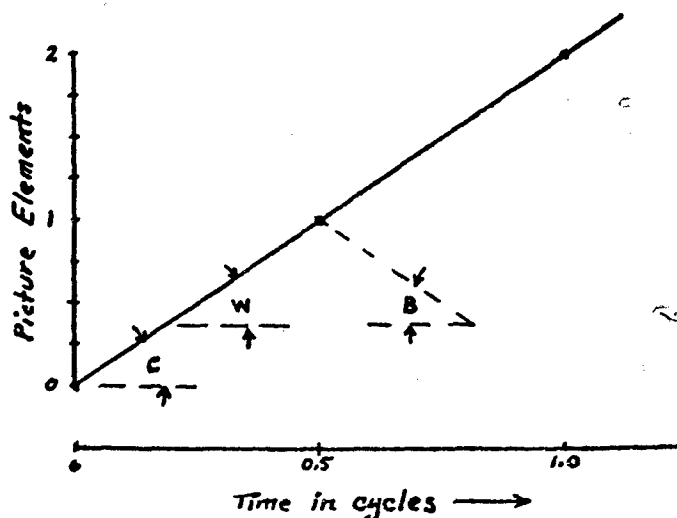
(B.)  
Pulse #1. Timer set  
at 0° crossings.



(C.)  
Pulse #2. Timer set  
at 180° crossings.



(D.)  
Sum of Pulses #1 & #2.  
Pulses above threshold  
used to reverse scan.  
direction.



(E.)  
Current to yoke.  
Angle W is linear  
rise for white.  
Angle B is reverse  
for pulse duration.  
Angle C is average  
white scan rate  
 $C = W$  for white.

Fig. 4 Scanning white copy with pulse time control.

M. ARTZT  
May 3, 1960

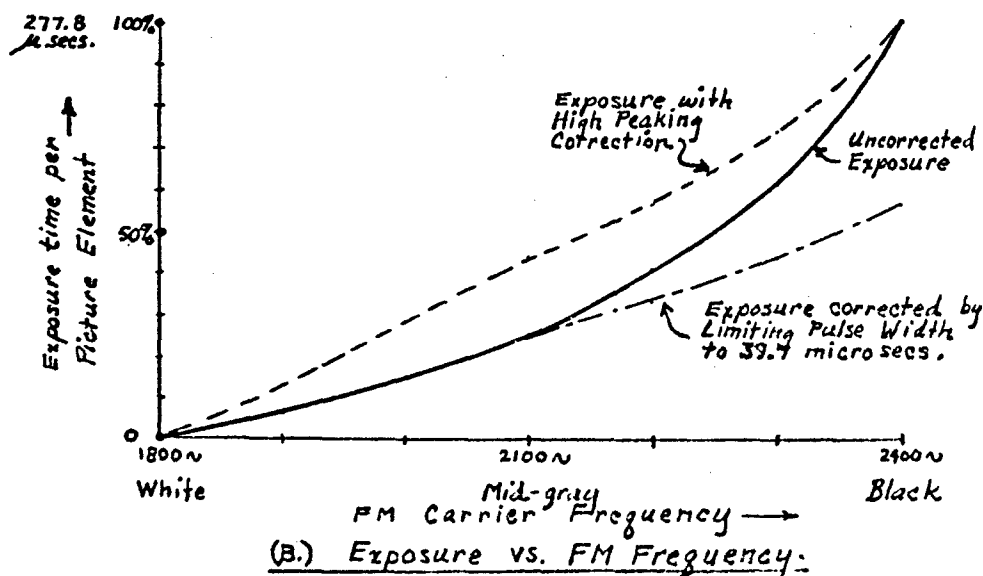
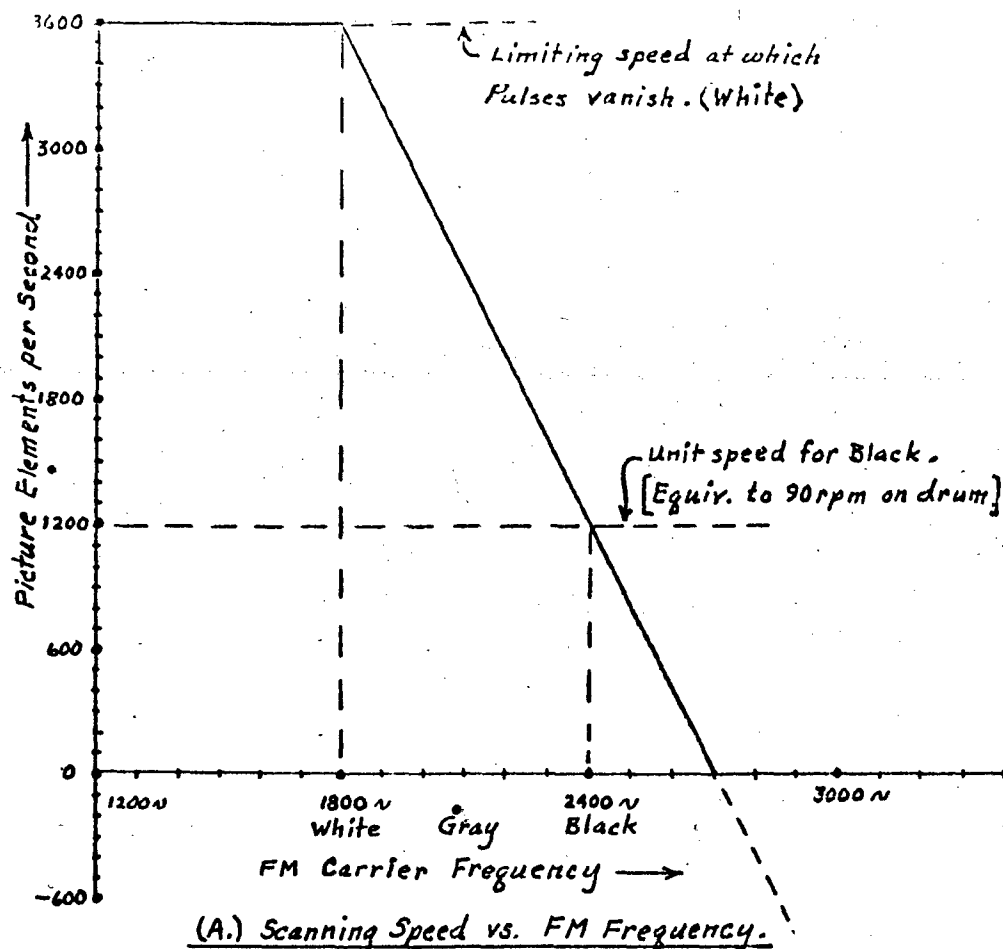


Fig. 5. Speed and Exposure vs. FM Frequency.

M. ARTZT  
May 3, 1960